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ABSTRACT

This paper describes the construction and use of a simple salinometer. The salinometer is composed, mainly, of a milliammeter and a battery and uses the measurement of current flow to determine the salinity of water. A complete list of materials is given, as are details of construction and operation of the equipment. The use of the salinometer in various science courses is discussed and a sample lesson plan is given. (BB)

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DETERMINING SALINITY BY SIMPLE MEANS

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SE 025 071

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INTRODUCTION

When Harold Goodwin embarked upon the task of defining Maine Education for the American Public the chore was not undertaken in isolation. Goodwin, in consort with the participants of twenty-six marine education conferences held throughout the United States between December 1976 and March 1978, produced "The Need For Marine and Aquatic Education" (Goodwin and Schaadt, 1978). The document now stands as a general guide for future Marine Education curriculum development. In addition, because of the broad base of support given during its synthesis stage it might be considered a mandate for the future in the Maine Education field.

Explicit amongst educators of the United States, according to Goodwin and Schaadt (1978), were three points which have far reaching ramifications for the future of Marine Education. Those points were that (1) if the ocean environment is to be preserved for future generations, citizens must be aware of the many ways their daily lives are integrated with the events which take place on, in, and under the ocean; (2) the educational curriculum, regardless of where it is, will not stand the inclusion of the additional subject; and (3) marine education programs should be cross-disciplinary, should begin soon after birth, and should continue on into adult life. This set of curriculum activities was designed to address all of these concerns as they relate to the concept of salinity.

DISCUSSION

While it is generally known that the salinity of the World Ocean can be attributed to dissolved salts, there seems no general agreement about how to impart the concept of salinity to students. If samples of sea and fresh water in transparent containers are held side-by-side in front of a light source, it is virtually impossible to detect differences between them. However, if the samples

are tasted a sensual difference is encountered. If the samples are allowed to evaporate, one would leave a crystalline residue while the other would not. If electrodes attached to a voltage source were placed some distance apart, first in one sample then in the other, one sample would be found a good conductor of electricity and the other a poor conductor of electricity.

If freezing and boiling points were compared between saline and fresh water, differences would be found. Also, if densities were compared between the two types of waters, that of fresh water would be less than that of saline water. Additionally, although not directly related to ocean salinity, an essential portion of the human diet is salt.

While the facts provided here are only a few of the total related to the concept of salinity, the question still remains of how to teach salinity based upon conclusions drawn from Goodwin and Schaadt (1978). It seems reasonable that when taken in its cross-disciplinary context the salinity concept may be infused into history, human physiology, physics, electricity, mathematics, chemistry, biology, and perhaps other courses. For example, the Chinese peoples have for thousands of years collected and evaporated sea water to gather sea salt. This in itself places salinity in an historical context and suggests a way in which man is dependent upon the sea for his existence. It is, of course, possible to imagine many additional examples in the several subject areas suggested above.

PURPOSE

The primary purpose of this paper is to present in depth one simple method of salinity determination, using a homemade and inexpensive piece of equipment. Further, to present the cross-disciplinary possibilities provided through the equipment's use. Finally, to briefly present other inexpensive and uncomplicated salinity evaluation tools and methods.

PRIMARY EQUIPMENT. Because salts ionize when they become dissolved in a solute, they impart to the solution the ability to conduct current. It is the magnitude of this current flow that is used to ascertain the salinity of a sample of salt water.

MATERIALS. The following materials are necessary for the construction of a simple salinometer:

1. One milliammeter - the range of the meter is dependent upon the size of the battery with which it is to be used. If a 1.5-volt battery is chosen then a 0-50 milliamp, full-scale deflection meter may be used. If a 6-volt battery is chosen, then a meter whose full-scale deflection is approximately 600 milliamp must be used.
2. One battery - the battery may be any size; however, its size will determine the size of the meter to be used.
3. One spring-loaded on/off toggle switch, loaded such that it must be pressed to remain on.
4. One block of wood approximately 2.5cm X 2.5cm X 10cm.
5. Two stainless-steel electrodes 2.5cm X 2.4mm X 12.5cm.
6. Four 25cm. lengths of number ten stranded wire with alligator clips fastened to each end.
7. Approximately 25cm. of marlin or other tying material which will not stretch when immersed in water.
8. One 100 ml. beaker.
9. The equipment, when constructed, may be housed in a wooden box; however, this is not necessary.
10. A quantity of sea salts.
11. A quantity of distilled water.
12. Two one-liter containers.
13. One stirring paddle.

14. One thermometer, calibrated in degrees centigrade.

15. One singlearm or pan balance.

These materials are readily available from scientific supply houses and local hardware stores. Meters may often be obtained from old radio transmitters. (A meter procured from such a source lowers the production cost)

CONSTUCTION. Physical construction of the equipment is shown in Figure 1, while schematic diagram of the equipment is provided in Figure 2.

FIGURE I. PHYSICAL CONSTRUCTION OF THE SALINOMETER

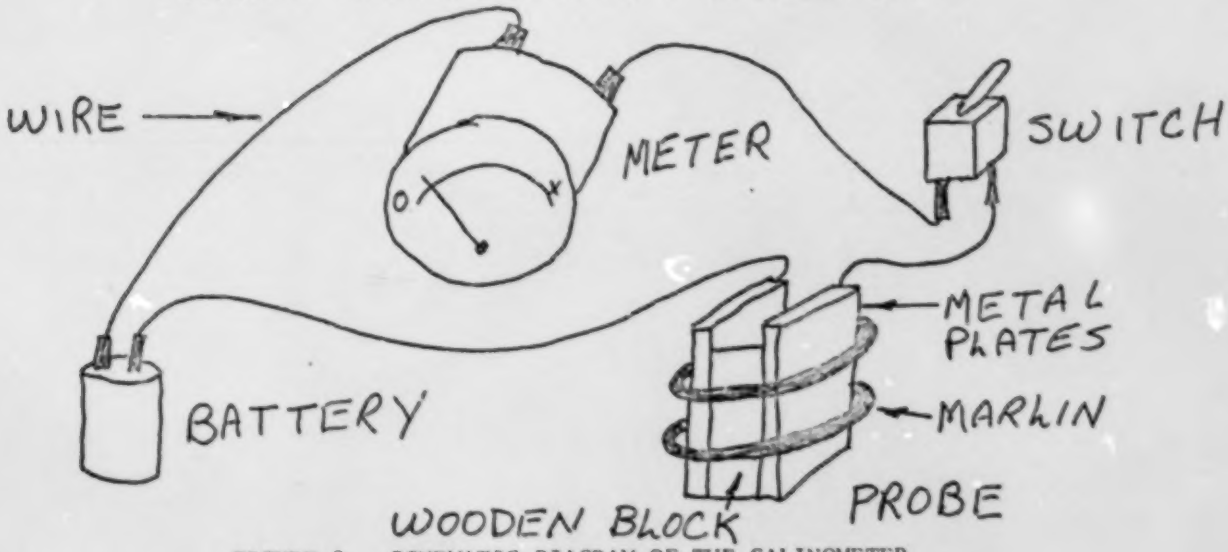
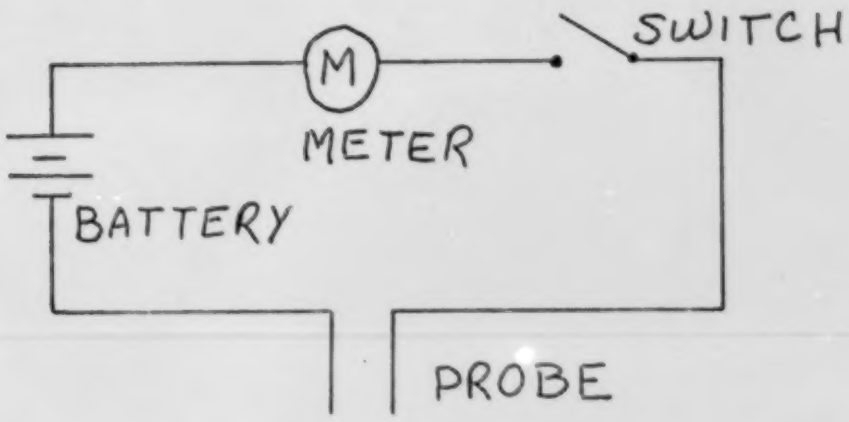


FIGURE 2. SCHEMATIC DIAGRAM OF THE SALINOMETER



The meter, battery, and switch may be housed in some sort of a container if the builders so desire, but this is not a necessity.

EQUIPMENT OPERATION. If a saltwater sample is obtained, placed in the beaker, the probe subsequently inserted in the sample and the spring-loaded switch momentarily held in the "on" position, current will flow between negative and positive plates of the probe, causing the meter to read. The meter reading will reflect the magnitude of current flow during the time which the switch is closed. Also, the magnitude of the reading will be directly proportional to the salinity of the sample. For example: a sample whose salinity, if 17 o/oo (where o/oo means parts of salt per thousand parts of sea water), will produce a smaller reading than a sample whose salinity is 35 o/oo.

When placed in water, sodium chloride (NaCl) ionizes to produce Na^+ and Cl^- ions.

$$NaCl \xrightarrow{water} Na^+ + Cl^-$$

While this is somewhat of an over-simplification of all the ionization reactions that actually take place in seawater, it is the basic reaction upon which the salinometer depends. If sodium and chlorine ions are present in solution then when an excess of electrons (e^-) appear on the negative plate of the probe (electron flow) they will be carried to the positive plate of the probe (negative and positive probes), (leads to the assumption that there is a difference in potential between probes); therefore, the circuit is complete, and the meter will read. Again, the greater the concentration of negative and positive ions in solution, the greater the number of e^- that will be moved from one plate of the probe to the other per unit time, and, so, the greater the indicated current flow will be.

EQUIPMENT CALIBRATION. Within the normal salinity range of the world ocean (8 or 9 o/oo in brackish water to perhaps 40 o/oo in highly saline areas) current flow is a linear function of salinity. Accordingly, it is possible to make a chart of, say, each part per thousand from 8 o/oo through 40 o/oo for a given temperature. Such a chart is shown in Figure 3.

FIGURE 3. A PLOT OF SALINITY VS. CURRENT FLOW FOR 20°C

Current In Milliamps	Temp In °C	8	9	10	11	Salinity in o/oo
	0					
	1					
	2					

This method requires the mixing of as many as 32 different salinity solutions and the measuring of current flow for each salinity sample at perhaps 70 different temperatures (since density varies with temperature, salinity also varies with temperature). A truly laborious task. However, since the function is linear for a given temperature, a graph of current flow versus temperature may be made in an XY coordinate system for that temperature. The generalized formula for the plot of a line in this system is:

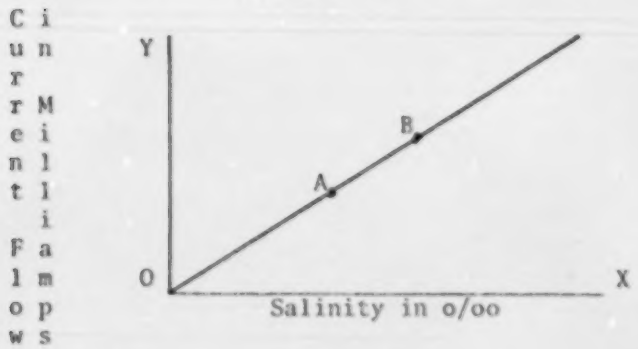
$$Y = mx + b$$

Where m is the slope, b the y axis intercept of the plot, and x and y the coordinates of any given point.

An XY coordinate system graph may be made as long as the x and y coordinates of two points are known within the system. Because current flow is dependent

upon salinity, current flow values should be plotted along the y axis and salinity values along the x axis. An example of such a plot is shown in Figure 4.

FIGURE 4. EXAMPLE OF AN XY COORDINATE SYSTEM FOR CURRENT FLOW VS. SALINITY FOR ____ °C.



In this system, the y coordinate of each point will be a current flow value and the x coordinate a salinity value.

Establishing the x and y coordinate values for two points requires that two samples of known salinity be evaluated for current flow by inserting the probe in a sample (remember that the sample must be raised or lowered to the desired temperature) momentarily closing the switch and subsequently recording the magnitude of current flow.

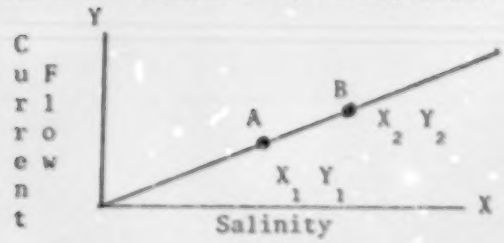
Two samples of known salinity may be mixed, using sea salts. For example, samples of 20 o/oo and 35 o/oo could be mixed. This may be simply accomplished by weighing 20g and 35g of sea salts and placing these masses in separate one-liter containers. Following this step, sufficient distilled water is added to each container to make the volume of each equivalent to one liter. Once the solution has been thoroughly mixed, the temperature may be adjusted and a current flow reading taken.

Coordinate data from the two points may be used to compute the slope of the line where slope is defined as rise divided by run. If, as shown in

Figure 5, point A is assigned the XY coordinates XY and point B, X_1 Y_1 then:

$$\text{Slope} = m = \frac{\text{rise}}{\text{run}} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

FIGURE 5. POINTS A AND B AND THEIR ASSIGNED XY COORDINATES



After the slope has been computed, there remains but one variable to identify in the formula $Y = mx + b$, that of the Y intercept, b. The value of b is derived by substituting the XY coordinates of one chosen salinity value, the value of m (derived above) and solving the formula for the remaining unknown (b). For example, suppose a salinity of 35 o/oo produces a current flow of 300 milliamps and the value of slope of the line at some temperature is 3, then:

$$b = Y - mx$$
$$= 300 - (3 \times 35)$$
$$= 300 - 105$$
$$= 195$$

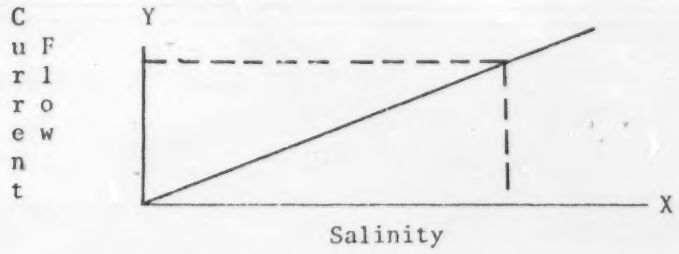
The equation, then, for the curve (say, that shown in Figure 5) at some temperature is:

$$Y = 3x + 195$$

It follows that once the equation for the specific curve (in this case the curve is a straight line) has been derived, the salinity may be obtained for any sample at that temperature by substituting the current flow figure for the sample and solving the equation.

Although the equation makes the identification of salinity quite easy, the XY coordinate graph remains useful. If a plot of salinity at a given temperature is made, then once current flow through that sample at that temperature has been found, the salinity may be rapidly obtained. All that need be done is to locate the current flow figure on the Y axis. Where the Y value intersects the curve and, subsequently, where a line from that point intersects the X axis, is the salinity of the sample. This process is shown in Figure 6.

FIGURE 6. ASCERTAINING THE SALINITY OF A SAMPLE FOR A KNOWN CURRENT FLOW.



While it is true that substantial initial computation must still be accomplished if the salinometer is to be used over a wide temperature range, students may obtain accurate data for their purposes if they make graphs in increments of 5^0C. In this regard, it might be convenient to begin at 0^0C and proceed through 20^0C.

THE SALINOMETER AS AN EDUCATIONAL TOOL

Regardless of the discipline, there are several generalized skills which may be imparted through the construction and use of the salinometer. First, the construction phase provides mechanical experience in constructing such a device. The use phase, on the other hand, provides experience-controlling variables. Salinity, for example, is held constant while current flow is evaluated in terms of changing temperature.

Perhaps the greatest experience to be gained from the union of the construction and use phases is the experience of using several sciences (chemistry, physics, mathematics) and some elementary technology to evaluate insitu conditions.

THE SALINOMETER IN CROSS-DISCIPLINARY STUDIES

It was mentioned, previously, that only through cross-disciplinary study is it possible to conceptualize the integral relationship between man and the marine environment. This point shall not be discussed further except to point out that the concept of salinity may be approached from several subject areas. Therefore, the salinometer may be used in several subject areas without specifically referring to its original intent, and the combination of its use across these areas may help students gain a more perfect understanding of salinity.

PHYSICS. Ohm's Law states that resistance is independent of current and voltage, and that for a given circuit resistance a certain amount of current will flow for a given amount of applied voltage.

$$\text{CIRCUIT RESISTANCE} = \frac{\text{voltage applied}}{\text{current flow}}$$

Restated, circuit current flow is directly proportional to applied voltage and inversely proportional to circuit resistance. Since applied voltage (battery voltage) is known, it is possible to study the relationship between current flow and resistance by inserting the probe in samples of varying salinities. In spite of the fact that the student is really studying electrical physics, a certain intuition is gained concerning the effect of salt upon water.

MATHEMATICS. The salinometer may be used in studying Cartesian coordinates. Accordingly, points in two dimensional space may be plotted in an XY

coordinate system. Each point is identified by its X and Y coordinates and each location is unique. Using this system as is done above allows plotting the curve of salinity data.

Although it is possible to use Cartesian mathematics in many subject areas, applying salinity data to the XY coordinate system allows visualization of the salinity vs. current flow data while also studying the mathematics of the system. Again, the concept of salinity can be an integral part of a subject area other than the marine sciences.

CHEMISTRY. The salinity data gathered by the salinometer may be used to study the concepts of normality, molarity, and equivalent weights, as well as the concept of ionization. For example, a certain salinity in o/oo is equatable to a certain normality, molarity, and a certain number of equivalent weights. Since, at a salinity of 35 o/oo (according to the definition of salinity) each 1,000 parts of sea water contains 35 parts of salt, one liter of sea water will contain 35 grams of salt; therefore, since one mole of salt (for discussion purposes NaCl is used) is equivalent to 28g, one liter of such sea water is a 1.25 molar solution. In this case, the 35 o/oo solution is also a 1.25 normal solution.

As is seen, the salinometer data can be used to teach basic concepts in chemistry while at the same time developing the concept of salinity.

ELECTRICITY. Basic electricity courses, as some physics courses, deal with Ohm's Law. It is possible, therefore, to study the relationships between current voltage and resistance by using samples of varying salinities. As was mentioned in the physics course discussion, the data for these studies are gathered with the salinometer. Again, although resistance, voltage, and current flow are the subjects of study, a certain intuitive understanding of salinity may be developed.

While it is possible to continue ad infinitum with the aspects of cross-

disciplinary study, the point is well taken that the salinity concept crosses many academic boundaries. Further, the salinometer discussed herein is useful in most of these academic areas.

THE SALINOMETER AND A SAMPLE LESSON PLAN

TITLE: Constructing and Using a Simple Salinometer

OBJECTIVES:

1. To provide experience assembling a simple piece of data-gathering equipment.
2. To provide experience calibrating a simple salinometer.
3. To introduce students to the theory upon which the salinometer they build is based.

MATERIALS:

Chalk, blackboard, milliammeter, battery, on/off toggle switch, block of wood, stainless steel electrodes, stranded electrical wire, beaker, sea salts, distilled water, one-liter containers, stirring paddle, thermometer, balance, marlin, alligator clips.

INTRODUCTION:

The major difference between saline water and fresh water is the former's salt content. The number of parts of salt per thousand parts of sea water determines species composition in an area, the buoyancy of floating objects, the water's freezing and boiling points, etc. Therefore, if, by some method, salinity can be measured, a great deal may be quickly inferred about the area from which the sample originated.

Salinity may be measured by a variety of methods. Today, we shall study one of those methods and build a device which puts that method to practice.

PRESENTATION:

Lecture about and demonstrate the following:

1. Physical construction of the salinometer.

A. Choice of battery and meter sizes.

B. Probe assembly.

(1) Place the block of wood between the electrode.

(2) Tie the electrodes and block of wood together with marlin.

C. Instrument assembly.

(1) Fasten alligator clips to each end of four 10cm lengths of wire.

(2) Connect the lengths of wire as follows:

a. negative pole of the battery to negative terminal of the meter.

b. positive terminal of the meter to the on/off switch.

c. from the on/off switch to one electrode.

d. from the second electrode to the positive terminal of the battery.

2. Equipment calibration.

A. Chemistry of sea water.

(1) ionization of salt.

(2) carrying of electrons from negative to positive plates of the probe.

B. Ohm's Law.

C. Mathematics of an XY coordinate system.

D. Drawing graphs related to the coordinate system.

E. Mixing solutions of various salinities.

F. Data collection related to graphs.

G. Drawing graphs related to a specific salinometer.

APPLICATION:

Have each student make graphs for 20^0, 25^0, and 30^0C at salinities of 10, 20, 30, and 40 o/oo.

SUMMARY:

Being able to ascertain the salinities of sea water samples drawn from different locations and depths, leads to understanding why other events are prone to occur or exist.

ADDITIONAL SIMPLE METHODS OF INVESTIGATING SALINITY

There are many ways students may study salinity. Those ways range from the simple to the abstract. However, while some methods are unsophisticated and, therefore, seem juvenile when dealing with older students, it should be realized that the term "salt water" does not have great meaning to the majority of people. Rarely is a connection made between table salt and salt water. Thus, regardless of students' ages, beginning with the simple may better aid students' ability to conceptualize the meaning of salinity than assuming that because of students' ages a certain method should not be used. In reality, perhaps true understanding may be gained only by using a variety of methods.

1. EVAPORATION. The evaporation method of evaluating salinity is qualitative, and since the actual existence of salts in sea water is quite abstract the method may be used to reduce the degree of abstraction. It requires two petri or other small dishes and quantities of sea and fresh water.

Equal volumes of sea and fresh water are placed in two separate dishes and the water allowed to evaporate. The process may be expedited by driving off the water with heat. Once the water has evaporated, students discover that one volume contained a solid while the other did not (fresh water with sufficient mineral content may have some mineral residue). The remaining salt crystals may be examined with hand lenses, microscopes, and other tools used by crystallographers.

A quantitive section may be added to this activity. It requires weighing the equal volumes of the two water types and their containers prior to evaporation. After evaporation the data and observations are compared and dis-

cussed.

2. FLOATING BLOCKS. The floating-block experiment, as well as those which follow it, are more abstract than the Evaporation experiment. They rely to some extent upon the student's intuition to relate observations and salinity.

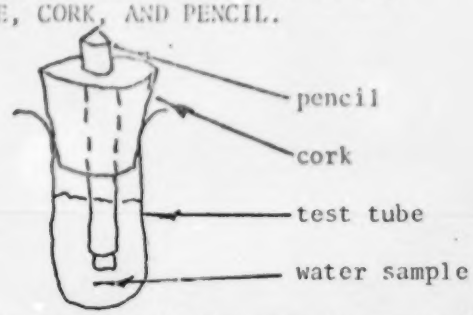
The floating-block experiment requires two wood blocks of equal size. One block should, perhaps, be pine, and the other some obviously different type of wood. Oak or balsa are equally good choices. In addition, the activity requires quantities of sea and fresh water, two large dishes, and a waterproof pen.

Once the different water types have been placed in separate dishes, both blocks are placed in the fresh water. Then, a line is drawn with the marking pen at the water line on each block. The blocks are then shifted to the salt water and the marking process repeated (the observed difference may be accentuated by using salt water of a high salinity value). Following these steps, the student's observations are discussed.

While this exercise does not deal directly with the salinity of the water but rather with its density ($D = M/V$), there is a relationship. The exercise also brings the student to a point where he or she is required to control variables. The primary reason for using blocks of different types is to lead the student to the realization that the water type and not the wood type is responsible for the observations. Additional control may be added by requiring students to control the temperature of the water in each dish.

3. TEST TUBE, PENCIL, AND CORK. A test tube, pencil, and cork may be used to build a simple hydrometer. The instrument is constructed by drilling a hole slightly larger than a pencil through the center of the cork and then placing the cork in the test tube. (See Figure 7).

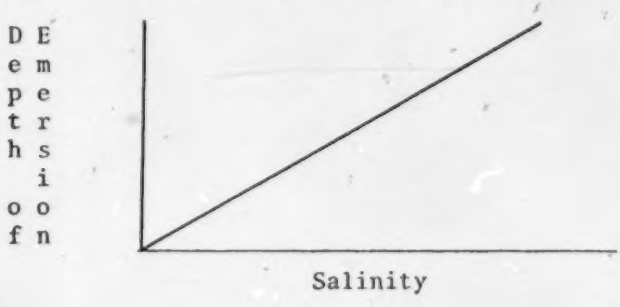
FIGURE 7. A SIMPLE HYDROMETER USING A TEST TUBE, CORK, AND PENCIL.



When a water sample is to be evaluated, the cork is removed, the test tube filled to about the 3/4 mark, the cork reinserted in the test tube, the pencil placed in the hole and allowed to seek its own level.

The instrument may be calibrated by comparing the level to which a pencil sinks in all samples, to that of distilled water. If a water-proof mark is made on the pencil, reflecting the water line of distilled water, the user has a point of departure for comparison. It is then possible, using waters of known salinity values to construct a graph of salinity versus amount of emersion of the pencil (see Figure 8).

FIGURE 8. SALINITY VERSUS DEPTH OF EMERSION



Instrument reading is facilitated by graduating the pencil with the water-proof marks. A mark per millimeter of pencil is a convenient scale.

Again, the activity deals with density but, in reality, salinity is measured.

4. BOILING POINT ELEVATION. In this activity, the student boils a sample

of fresh water and several others of differing but known salinities. Boiling point data are gathered and compared and then an XY coordinate graph is drawn Once the graph is drawn the salinity of an unknown is ascertained by referring its boiling point to the graph.

5. FREEZING POINT ELEVATION. An activity identical to that of Boiling Point Elevation may be conducted, using the freezing points of samples.

CONCLUSIONS

Salt is an extremely important ingredient in human life. Its true importance can be known only by pursuing the matter from a variety of academic points of view. Further, the concept or true meaning of salinity may also be approached from a variety of directions. Some of those directions have been explored above. However, they are not the only methods students may use to gain an understanding of salinity. From a scientific, mathematical perspective, there are many additional ways to evaluate salinity. Some are much less and some much more sophisticated than those considered here. The use of any method or combination of methods is left to the individual instructor's perceptions of his or her students' needs.

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